Annexure-5

Design and analysis of Coherent Routing Protocols for message forwarding in Opportunistic IoT Networks

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to

Manav Rachna University

by

S P Ajith Kumar,
2K19-PFE-005

Under the supervision of

Dr. Hardeo Kumar Thakur
Associate Professor
Department of Computer Science and Technology
Faculty of Engineering
Manav Rachna University

Year 2019

MANAV RACHNA
vidyanatariksha
MANAV RACHNA UNIVERSITY
(FORMERLY MANAV RACHNA COLLEGE OF ENGINEERING
NAAC ACCREDITED 'A' GRADE INSTITUTION)
Declared as State Private University under section 2f of the UGC act, 1956

MANAV RACHNA
Vidyapeeth Shal

MANAV RACHNA UNIVERSITY
(FORMERLY MANAV RACHNA COLLEGE OF ENGINEERING
NAAC ACCREDITED 'A' GRADE INSTITUTION)

Declared as State Private University under section 2f of the UGC act, 1956

DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis **"Design and analysis of Coherent Routing Protocols for message forwarding in Opportunistic IoT Networks"** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in **Department of Computer Science and Technology** under Faculty of Engineering of Manav Rachna University, Faridabad during the academic year 2020-21.

It is a bona-fide record of original work carried out under the supervision of **Dr. Hardeo Kumar Thakur,** Associate Professor, Department of Computer Science and Technology, Manav Rachna University has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that short synopsis is within the plagiarism limit and copy of the same is attached as per University norms.

S P Ajith Kumar
2K19-PFE-005

Hardeo

Dr. Hardeo Kumar Thakur
Associate Professor
Department of CST
(Supervisor)

Susmita Ray

Chairman, DRC

Proposed Title: Design and analysis of Coherent Routing Protocols for message forwarding in Opportunistic IoT Networks

ABSTRACT

Opportunistic Internet of Things [OppIoT] networks are one of the effective evolutions of Delay Tolerant Networks (DTNs). OppIoTs are different from Internet of Things network as end-to-end routing paths may not be available from the source to destination. It operates in an intermittent, mobile communication topology, employing peer-to-peer transmission, hops on a store-carry-forward basis. In this network routes are building dynamically, whenever messages are routed from the source to destination(s), any potential node will act as the next hop, bringing the message nearer to the destination.

This is necessary to develop routing protocols which are able to increase the message delivery possibility and decrease the delivery failure possibility. Many protocols like Epidemic, PROPHET, Spray and Wait, MLPROPH, KNNR, GMMR etc… used in Opportunistic IoT networks. Most of these protocols suffer from overheads like higher power and memory requirements, large delays, generalization in their approach in a dynamic, mobile environment, misrepresentation of the node attributes in wrong cluster etc.

Machine learning is a tool for learning from histories used to select next hop to forward message under store-carry-forward scheme to reach the message to final destination. The trained machine learning model exploits information in delivery predictability from buffer availability, success ratio, transmission speed, power of the node and message live time. We explore routing protocols based on fuzzy for the opportunistic IoT network considering floating point values between 0 and 1, as a result, it becomes convenient to collect the best nodes.

Keywords: Opportunistic Internet of Things, Delay Tolerant Networks, fuzzy, Machine Learning.

CONTENTS

S. No.	Description	Page No.
1	**Introduction**	1-5
	1.1 Block diagram of Opportunistic & IoT Networks	
	1.2 Characteristics of Opportunistic IoT Networks	
	1.3 Opportunism in mobile IoT networks	
	1.4 Architecture of OppIoT networks	
	1.5 Application Areas of OppIoT Networks	
2	**Literature Review**	6-11
	2.1 Opportunistic IoT Routing	
	2.2 The First Contact Protocol	
	2.3 Direct Contact Protocol	
	2.4 Epidemic routing protocol	
	2.5 Spray and Wait protocol	
	2.6 PROPHET protocol	
	2.7 MLProph protocol	
	2.8 KNNR protocol	
	2.9 GMMR protocol	
	2.10 CAML protocol	
	2.11 RLProph protocol	
3	**Description of Broad Area**	12-13
4	**Objectives of the Study**	14-15
5	**Methodology to be adopted**	16-18
6	**Expected Outcome of the Research**	19
7	**References**	20-23

Chapter 1

INTRODUCTION

Opportunistic network [1] has been emerging as one of the foremost recent and fascinating evolutions of the MANETs paradigm. They have all the challenges and problems faced by MANETs and they have also some new challenges. In Opportunistic networks, when there is no path exists from source to destination the message routing is constructed based on opportunistic contacts through the intermediate nodes are called Store-Carry-Forward technique and it happens local forwarding from one node to another. This Opportunistic network is a subclass of Delay tolerant networks (DTNs) [2] as several observations are derived from DTNs. In Opportunistic IoT [OppIoT] networks the source to destination end-to-end path never happens or may happen only for a very small and volatile duration of time. The construction of routes in these networks are not static, but dynamic and the source node picks any node from the cluster of neighbours as the next hop thinking that it will deliver the message to the destination.

Internet of Things(IoT) based technologies [27] traditionally encompass a system of computing devices in addition to analog and digital machines equipped with the talent to exploit data transfer over a network without much human intervention. With the advent of technologies, there have been competing approaches in the development sphere to minimise various overheads and at the same time increase functionalities of these IoT based devices. These techniques are primarily based on artificial intelligence and machine learning to ameliorate the decisive power so as to strategize a plan of action in both the routing and processing phases for these IoT devices. Trends indicate these devices have increasingly become more mobile in nature and these mobile IoT devices are prevalent in the form of wearable or human-associated technologies. Owing to this nature of the devices we often experience their mobility pattern emulating the mobility of their human host directly or indirectly giving rise to social concept based routing which is exploited in the development of the proposed scheme. Often these devices communicate in groups or function as a part of a larger group thus creating an IoT network. This network entails heterogeneous IoT devices which without a human to human or human to machine interaction have the ability to communicate and route data packets in the network.

1.1 Block diagram of Opportunistic & IoT Networks

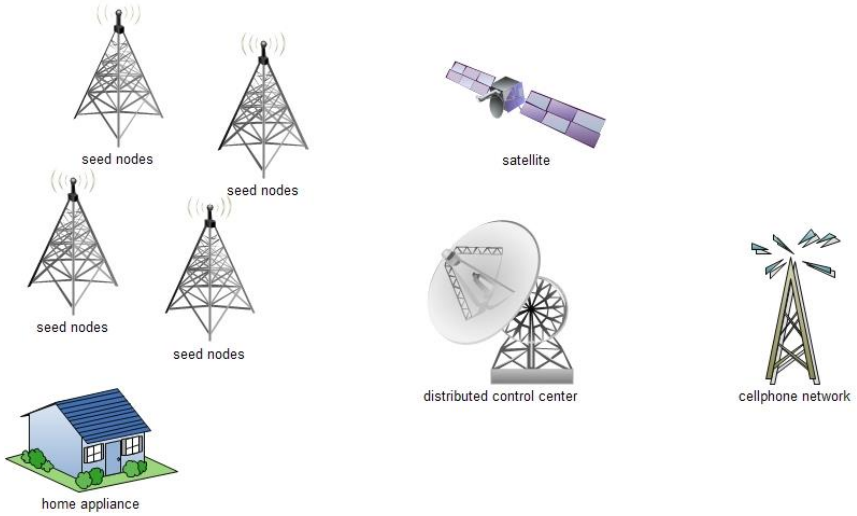


Figure 1.1 Opportunistic Network

In Opportunistic Networks, nodes may be either static or movable like pedestrian users and vehicles, but normally they are mobile. The nodes are using all the communication medias such as WiFi[5], Bluetooth [4], cellular [6] etc. to contact and communicate each other. Every OppNet starts from a seed node. In the starting it consists of one node. The seed breeds into a larger network by extending invitations to link the OppNet [1] to close devices, node clusters or close to systems that is capable to make contact. For example, Figure 1.1 shows a seed OppNet that nurtured into an expanded OppNet by adding several helpers [1].

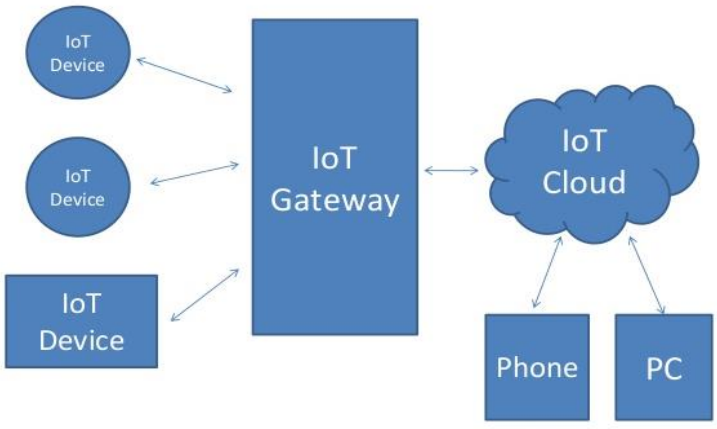


Figure 1.2 IoT

An IoT network comprises of nodes which are embedded in network for sensing, actuation and communicating with various communication protocols such as Internet, WiFi, Bluetooth, M-bus etc.,. These protocols provide connectivity between nodes within network. The communication network provides connectivity to remote area networks. To enable the communication between remote networks gateways are used. In IoT data is composed in the cloud and accessed by cloud applications like remote diagnosis, enterprise applications, management applications and analytics applications etc.

1.2 Characteristics of Opportunistic IoT Networks

Some of the most important characteristics of OppIoT networks are [3]:

- It is derived from Delay- Tolerant Network (DTN)
- It is a light network
- It has fewer intermittent Contacts
- It has no end-to-end link
- It uses Store, Carry and Forward Mechanism in Routing
- It uses infrastructure less protocols
- The link performance is highly variable.
- It makes smart things.
- It build effective business intelligence and real-time analysing by connecting all the relevant things.

1.3 Opportunism in mobile IoT networks

In OppIoT, the massive delays in propagation and the irregular queuing may cause breaking and this adds to issues as the traditional protocols make an implicit assumption of receiving prompt acknowledgement, hence they fail to operate in these scenarios. There prevail asymmetric data rates and a high error rate in the transmission involving sparse networks. The solution to this impediment lies in the very thing that causes the mobile nature of the devices [28]. One such solution to enhance the above impediment is to make use of the mobile nature of the nodes in the network and the ability to locally forward data. When opportunistic contacts are established, the intermediate nodes can forward the data successively and so as to route it to the destination. This is often referred to as a store-carry-forward mechanism which is prevalent in Opportunistic Networks abbreviated as OppIoT Networks. OppIoT Networks are

belong to broad category of Delay Tolerant Networks (DTNs). Here the contacts, also known as opportunities, are intermittent. The link connectivity or performance is extremely wavering and the end to end connectivity is for a brief unpredictable time hence the conventional Internet protocol suite will not function in this scenario [21]. This necessitated the confluence between devices, IoT deals with a large magnitude of information through networks that are inherently heterogeneous. In principle, OppIoT attributes similar properties of delay tolerance in comparison to traditional Opportunistic Networks. This is of great utility in several scenarios where the architecture of the network is lacking, key information pertaining to the configuration is absent and the nodes are following random mobility models [32]. The forwarding occurs here in a similar manner to that of Opportunistic Networks, when two or more nodes encounter within the communicable distance, this is followed by a delivery probability-based decision-making paradigm. The decision pertaining to whether to forward the node or not, this is termed as the next-hop selection.

1.4 Architecture of OppIoT networks

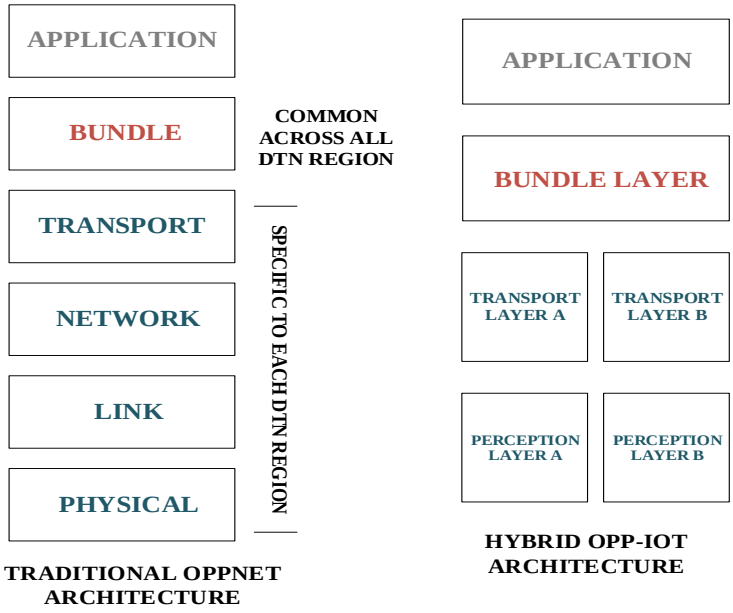


Figure 1.3 OppIoT Architecture

Figure 1.3 illustrates the hybrid OppIoT network Architecture. It may be noted this hybrid is a confluence of both elements of DTN and IoT based systems and includes elements

from both [19]. OppIoT architecture is designed to accommodate the disruptions and intermittent connectivity in a network with the infrastructure to address this heterogeneity.

There are a myriad of schemes and each of them has somewhat dissimilar semantics, a group of protocol centric convergence layer adapters facilitates the required utility to forward the data units known as bundles as per corresponding protocols. The end to end overlay is known as the bundle layer that is situated below the application layer and above the transport layer and. The devices that implement these are the nodes which in this case are the IoT devices. This essentially exists as an overlay that makes use of storage that is persistent which tackles the intermittent connectivity. Further, this entails a hop by hop transfer so as to ensure a reliable delivery with the ability for acknowledgement from end to end. Diagnostic features are included for interoperability and ease in usage of semantics. Further security nodes can also be embedded in this architecture in the form of designated nodes to prevent unauthorised usage [28].

1.5 Application Areas of OppIoT Networks

Opportunistic networks applications are [1, 8]:-

1. Message exchanges in developing areas
2. Interconnect mobile and rescue nodes in disaster areas
3. Scientific wildlife monitoring
4. Environment
5. Healthcare
6. Sensor networks
7. Smart Home
8. Smart City
9. Industrial Internet
10. Connected Car
11. Smart Supply Chain
12. Smart Retail
13. Smart Farming, etc…

Chapter 2

LITERATURE SURVEY ON ROUTING IN OPPIOT NETWORKS

To understand the routing in Opportunistic IoT Networks in a better way, the different types of routing protocols existing in the Opportunistic Networks and IoT were studied. This chapter presents the brief literature survey.

2.1 Opportunistic IoT Routing

Opportunistic IoT networks operate in an intermittent mobile communication topology, employing peer-to-peer transmission hops on a store-carry-forward basis. The irregular connectivity often occurs means that it is not guaranteed that end-to-end path from source to destination will not exist continuously. In OppIoT network nodes behaving as hosts and routers transfer messages to the gateways.

In Opportunistic IoT network the TCP/IP protocol scheme will not work due to long transmission delays and intermittent in nature. There is no assurance that the network will construct end-to-end route from source node to destination node. The opportunistic IoT resolve this issue by transmitting the message locally to the intermediate node in the path of source to end node and finally the message will reach close to the destination.

In view of intermittent communication topology of OppIoT Networks, the intermediate nodes may not meet nodes in the route consistently or frequently [9]. Sometime to take data nearer to the destination there might not be appropriate intermediate node, in this situation data may be delivered directly to the destination. For this, nodes have to keep the packet long time in the buffer.

When there is no forwarding chance towards the destination it uses Store-Carry-Forward technique by the intermediate nodes to move the packet. The intermediate nodes may come in contact with other nodes in the destination path because the network is dynamic in nature. In this way, the intermediate node forward the data more close to the destination.

Figure 2.1, explains how the Store-Carry-Forward technique and node's mobility can be used to send a data to the destination. Node S has a data to be delivered to node D but there is no path among S and D. The movement of nodes allows the data to be transmitted to node 3

at time t1, then transmitted to node 4 which comes in contact with time t2 at node 3 and then finally to node D which comes in contact with time t3 at node 4.

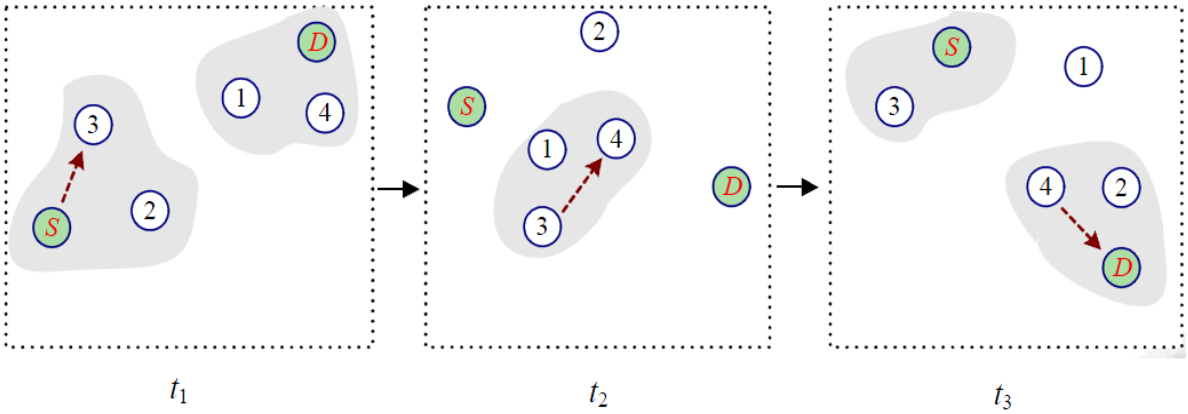


Figure 2.1: A data is sent from node S to D via nodes 3 and 4 through the mobility of nodes.

2.2 The First Contact Protocol

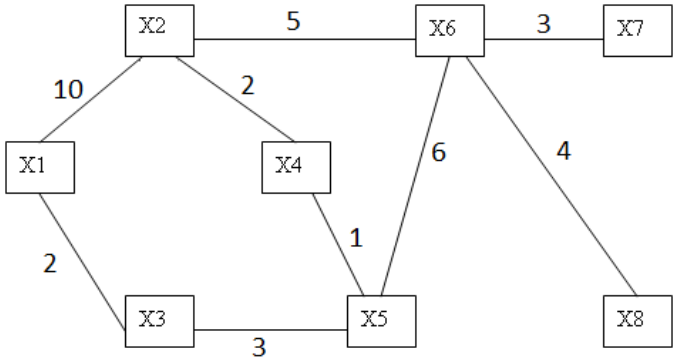


Fig. 2.2 First contact Protocol

The First contact protocol [10] randomly sends the messages to any neighbor node. The path chosen randomly to forward the message from all the available contacts. Suppose no path is available to send the message to the neighbor, the message will wait till it gets a path.

The example shows that the aim of this protocol is to send the message from node X1 to node X5. As per the figure 2.2, the node X1 sends the message to X2 or X3 according to its contact. Once it sends the message to neighbor node, the message is immediately removed from source node. Therefore only one copy of the message exists in the network. Suppose X1 first

contacts X2 then the message will be forwarded to X2 and X2 will forward in to the node X4 or X6. Subsequently X4 or X6 forward the message to the end point node X5. Otherwise if the node X1 forwards the message to X3, X3 will send the message to the end point node X5. Due to frequent contact of same nodes, sometime path loop may occur. In this first contact protocol, delivery ratio is poor due to path looping and keeping only a single copy of message in the network.

2.3 Direct Contact Protocol

In Direct Contact routing protocol [11], the message is not forwarded to the intermediate nodes by the starting node; instead the starting node holds the message till it makes a direct contact with the ending node. The message is directly delivered to the final destination. Hence every message is transmitted only one time. So both the resource utilization and usage of bandwidth are less for message transferring in this protocol method. If the starting node never encounters the ending node at any time then the delivery delay is boundless. Hence this protocol has long delays for delivering the message.

2.4 Epidemic routing protocol

This Epidemic routing protocol [12] has two buffers in each node. The first buffer contains the messages produced by the same node. The second buffer comprises of the messages received from the other nodes. A unique and single identification (ID) is attached to every message. A directory of message identification numbers is contained in its buffer and is maintained by each node. This list or directory is called the summary vector. As soon as any two nodes meets, they swap their summary vectors between each other. By means of collating the two summary vectors, the nodes collate those messages that they haven't contained with them. Once the process of message collection is finished, the nodes will begin to exchange the messages. This produces a huge quantity of message redundancy in the network.

2.5 Spray and Wait protocol

This Spray and Wait [13] protocol consists two phases. First one is called spray phase and second is wait phase. In spray phase source node transmits message to a fixed number of neighbor nodes and will wait for some time to reach message to the destination node. In the wait phase if the message does not reached to the destination, then each intermediate node

which contain message will act as source node. Using fixed number of flooding in wait phase this protocol limit the flooding level. As compared with epidemic routing protocol, spray and wait protocol having minimal number of transmissions.

2.6 PRoPHET

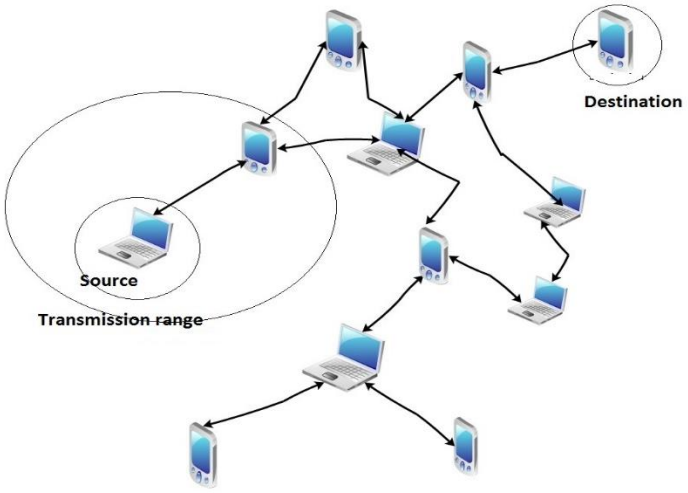


Fig: 2.3 PRoPHET Routing

Each node before sending the message in PRoPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) [14] computes delivery predictability. Delivery predictability between source node and destination node is achieved by estimating probability metric. The delivery predictability is prepared according to the history of visit to particular location or history of encounters between nodes. Each node containing summary vector is calculated by applying probabilistic metric used to find delivery predictability. At any given point of time two nodes meet they interchange their summary vector values. If two nodes meet frequently then these two nodes have higher delivery predictability and both are good forwarder for each other. Therefore if a node is willing to send message to another node will select neighbor node which is having higher delivery predictability. The simulation result of PRoPHET was compared with epidemic routing protocol and it was found out that PRoPHET had less communication overhead, higher delivery success rate, less delay and less message exchange.

2.7 MLProph

MLProph [23] is a probabilistic metric based approach for routing in opportunistic scenarios using machine learning. This protocol use a combination of neural network and machine learning to ascertain the probability of delivering messages successfully. To determine whether the message should be forwarded or not, it uses a two-tiered system such as PROPHET probability and ML probability. The trained machine learning model uses the following attributes to select the next hop to determine the delivery probability such us buffer availability, success ratio, transmission speed, speed of the node, power of the node and message live time. In the simulation, MLProph has been compared to PRoPHET to show its efficiency.

2.8 KNNR: K-Nearest Neighbour

K-Nearest Neighbour based Routing protocol (KNNR) [22] forward the messages using intermediate nodes towards the destination. It has two phases namely Training Phase and Application Phase. In training phase it create dataset and classifies it into two classes. “Class 0” represent the message is not be transferred and “Class 1” represents the message is to be transferred to the neighbour node. This dataset used in application phase for decision making. This protocol exploit the features of the past behaviour of the network, nodes and the data from the routing process to shortlist the intermediate nodes towards the destination. At every node encounter, the protocol evaluates the similarity of the intermediate node with the dataset using K-Nearest Neighbours algorithm and finds one of the closest intermediate node and transfer the message based on the class it belongs.

2.9 GMMR: A Gaussian Mixture Model

GMMR [37] employs Machine Learning based soft clustering technique, known as Gaussian Mixture Model based clustering. In a soft clustering technique, the clusters are allowed to be overlapping, with each node being free to exhibit multiple prominent characteristics, being represented by multiple clusters at once. GMMR utilizes expectation maximization (EM) algorithm for the judgement of dynamic cluster assignment, which is highly efficient in operation. This protocol has two phases namely Training phase and Routing phase. Training phase extract and store data from selected network features. The GMM will get trained on this dataset using EM algorithm. In routing phase trained GMM create clusters and

allot devices to every cluster. Now the message is forwarded to all devices which are in the same cluster as the destination of the message. This model is used to control flooding of messages.

2.10 CAML

OppIoT boils down to the analysing probabilities of delivering a message successfully to the next node, at every node encounter. CAML (CAscaded Machine Learning based) routing protocol [36] is one of the approaches in the literature that uses ML paradigms to automate the decision-making process. This protocol extract relevant inputs from the nodes of the network then make use of a pre-trained classifier to ascertain the value of delivery probability. It is computationally heavy and not feasible for where training needs to be more frequent.

2.11 RLProph

RLProph protocol [38] is a dynamic approach that makes use of Reinforced Learning (RL) OppIoT networks. This protocol proposes a way to completely make the opportunistic IoT routing process automatic by using the RL algorithm of Policy Iteration to maximize the possibility of successfully delivering the message. The agent selects certain actions from the previous timestamp based on the reward it obtains and states of the environment. This continuous loop of choosing actions for states that maximize the total possible reward is how an agent learns to optimize certain desirable behavior. The OppIoT routing environment is modelled as a discrete stochastic process termed as a Markov process where it define the elements for the RL model - agent, state, reward, action and environment. The optimal routing process is obtained as a result of solving the Markov decision process [MDP] using Policy Iteration.

Chapter 3

DESCRIPTION OF BROAD AREA

In Opportunistic networks message routing is constructed based on the connection among the nodes that occurs due to their node mobility is called Store-Carry-Forward technique and it happens local forwarding from one node to another. For sending the message to the end node, the protocol moves the message to the intermediate nearest nodes. Sometime to take data nearer to the destination there might not be appropriate intermediate node. In this situation data may be delivered directly to the destination. For this nodes have to keep the packet long time in the buffer. The above mentioned Store-Carry-and-Forward is an extremely noble technique to raise the possibility of message delivery to the end node in Opportunistic networks. Due to this reason opportunistic networks comes under Delay Tolerant Networks (DTNs) sub class. The nodes should have adequate buffer area to store all the messages therefore on avoid the dropping of packets till subsequent contact happens.

Due to the obscure quality and uneven performance of the nodes, routing and forwarding may be a hard task in opportunist networks. A lot of analysis done in opportunistic networks routing and forwarding region. In Oppnets a very important task is finding proper routes towards the desired destination. Thus, designing a new routing protocol in this situation is much in demand in the Oppnet. The protocol must be consumes less power and be energy efficient while forwarding the messages. The aim of the protocol is to decrease the communication delay and increase the successful data delivery rate to the target. The performance of the protocols are measured based on some metrics like number of messages delivered, delivery probability, average hop count, average delay etc.

Ranging from healthcare and finance to core development, there has been an emergence of the Internet of Things (IoT) based technologies [27]. Without much human intervention these technologies traditionally encompass a system of computing devices in addition to analog and digital machines equipped with the capacity to exploit data transfer in the network. But with novel trends and interdisciplinary approaches in development, this definition has become broader and all encompassing. With the advent of technologies, there have been competing approaches in the development sphere to minimise various overheads and at the same time

increase functionalities of these IoT based devices. These techniques are primarily based on artificial intelligence and machine learning to ameliorate the decisive power so as to strategize a plan of action in both the routing and processing phases for these IoT devices.

Trends indicate these devices have increasingly become more mobile in nature and these mobile IoT devices are prevalent in the form of wearable or human-associated technologies. Owing to this nature of the devices we often experience their mobility pattern emulating the mobility of their human host directly or indirectly giving rise to social concept based routing, which is exploited in the development of the proposed scheme. Often these devices communicate in groups or function as a part of a larger group thus creating an IoT network. This network entails heterogeneous IoT devices which without a human to human or human to machine interaction have the ability to communicate and route data packets in the network. Networks based on IoT devices have increasingly become more popular and often replaced their contemporary Wireless Sensor Networks (WSN) in lieu of increased functionality [31]. Additionally, these are used in conjunction with more complex heterogeneous devices to enable parallel processing and distributed computing for increased efficiency.

Machine Learning (ML) is one of the latest research topic in trending. Opportunistic IoT (OppIoT) network is a network where source to destination path is missing to route messages. Therefore to send message from one node to another node uses store-carry-forward concept is used where intermediate nodes carry message to the destination. Selection of best intermediate node ie) next hop who carries message will be decided by Machine learning algorithm. KNNR [22] and MLPROPH [23] Opportunistic routing protocols use ML in automating the decision making process to select next hop. To control flooding of messages in intermediate nodes we may use clustering technique, krop [24] opportunistic network routing protocol uses K-means clustering to control flooding of messages.

Chapter 4

OBJECTIVE OF THE STUDY

Opportunistic IoT networks operate in an intermittent, mobile communication topology, employing peer-to-peer transmission hops on a store-carry-forward basis. Such a network suffers from intermittent connectivity, lack of end to end route definition, resource constraints and uncertainties arising from a dynamic topology, given the mobility of participating nodes.

Machine learning is an instrumental tool for learning and many histories based machine learning paradigms like MLPROPH, KNNR and GMMR have been proposed for digital transformations in the field with varying degrees of success. This work aims at designing and analyzing novel schemes and algorithms to improve routing efficiency in infrastructure-less opportunistic IoT networks. It aims at developing an efficient routing protocol that can easily be applied to opportunistic IoT networks and provide efficient functionality even in the existing constraints.

- Classify the previously proposed routing algorithms and describe the main properties of the most popular algorithms for infrastructure-less opportunistic IoT networks.
- A new routing protocol will be developed for infrastructure-less opportunistic IoT networks and its advantages and disadvantages will be compared with already existing protocols.
- The nodes of OppIot Network have limited energy resources therefore any new technique used for communication defined should keep this constraint in mind like frequent disconnection and re-connection, Intermittent contacts, long delays etc. normally add complexity to routing and result in the reducing of energy of the device. Hence, energy efficiency of the routing technique may also be explored in this work.
- The new protocol should be implemented with acknowledgment based technique for the guaranteed information delivery in opportunistic networks.

- As the intermediate nodes use buffer to store the message, a buffer management system is desired when a new message arrives and the buffer is already full. Hence, buffer management technique will also be explored in this work.

- Secure opportunistic routing is needed to provide a safety shield for the secure communication among the nodes in infrastructure-less opportunistic IoT networks. It is necessary to design a protocol against various types of security threats underlying this environment. Hence, secured routing technique will also be explored in this work.

Chapter 5

METHODOLOGY TO BE ADOPTED

The Opportunistic IoT paradigm works on the conjuncture over the capability of the constituting entities to be able to interact freely, learn from these interactions and make intelligent decisions for message routing based on the knowledge gained from such interactions. The earliest propositions in opportunism that lays the foundation of the advancing field of OppIoT are history based algorithms, as introduced in the text earlier. Building on such a basis of operations, various learning paradigms have been used in the past to emulate topological knowledge into decision making strategy.

- Application of machine learning in an opportunistic environment is one of the solutions to an effective routing paradigm under minimal overhead usage, like MLPROPH. However, they might suffer from the lack of generalization in their approach in a dynamic, mobile environment, under representing the topological aspects involved, hence not giving an optimal solution.

- Lack of generalization can be solved by comparing likeliness to the ideal solution rather than locally ranking the best candidate. Clustering provides us with the opportunity to find such likeliness in features to that of the ideal solution. Clustering can occur either with hard boundaries or soft boundaries.

- Hard clustering segregates the nodes into non-overlapping partitions of the network topology. Such a segregation leads to the association of the node to a singular cluster. This shall lead to misrepresentation of the node attributes or even wrong cluster assignment by neglecting the other parameters that shall be prominently shaping up the node's behaviour.

- In Soft clustering technique, the clusters are allowed to be overlap, with each node being free to exhibit multiple prominent characteristics, being represented by multiple clusters at once. However, this decision-making paradigm does not account for the degree of representation of each cluster that the node is part of, hence, being unable to quantify the representation that each cluster has towards a node's behaviour.

- A fuzzy logic scheme allows partial participation of entities into different sets, allowing a better representation of real world entities. Here I propose employment of fuzzy clustering scheme for routing in OppIoT scenario, combining the ability of fuzzy logic to allow a quantified representation of characteristics of the network topology by the various topological partitions. These partitions are based upon the behaviour of the network topology and the nodes, shaped by the various interactions and historic behaviour of nodes during such interactions. Fuzzy clustering is a soft clustering technique that employs fuzzy logic for representation of degree of association of a node to the all existing topological partitions.

5.1 Proposed Scheme

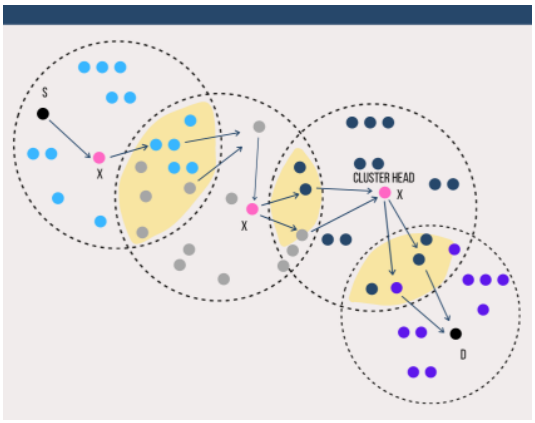


Fig. 5.1 Cluster formation and inter-cluster routing

Clustering allows division of entities into groups or cells of like attributes and features. Here, in this proposal, I intend to exploit this property of clustering techniques and utilize its heuristics for the grouping of nodes in the topology on the basis of some parameters. Such grouping shall allow an easier choice for the transmitting node to pick its next hop by looking for the node with characteristics that are most analogous to those of an ideal next hop.

History with Destination metric is representative of the transmission behaviour and history between the candidate and destination node, signifying the trust shared between the nodes. The above discussed parameters are used as features for training of the pre-trained clustering model, leading to the cluster formations. This is done with the help of fuzzy based clustering technique. The proposed scheme can be divided into three phases.

- **Topology partition initialization**

In this proposed scheme, I plan to adapt the heuristics of Fuzzy C-Means (FCM) clustering algorithm, is a soft clustering algorithm that allows partial membership of an entity into different clusters, based on its degree of likeness to the properties characterizing the cluster. This aspect of FCM allows a generalization of the trained clustering model, allowing a single entity to portray all its characteristics with weighted representation according to the importance of the said characteristic. Such a scheme allows a real-world representation of entities that might not be easily type casted into a single cluster but might display properties pertaining to multiple clusters in varying degrees of representation.

- **Model training and cluster formation**

For training of the clustering model, five parameters introduced before are used as features for data visualization and understanding the characteristics exhibited by the network. These features are collected from historical records of topological data including frequency of encounter, buffer space of nodes, messages carried by each node, successful deliveries of nodes and encounter history between nodes.

- **Dynamic node grouping and routing**

The above described paradigm trains the model to form different clusters representing the different major aspects of the network topology. The nodes, according to the attributes displayed by them during their various interactions between each other, are associated with one or more clusters. This grouping of identical nodes is then utilized for routing purposes, with nodes with like properties being highly likely to interact. With this knowledge, the transmitting node seeks a node in its neighbourhood that shall possess the attributes closest to the destination node, and hence is most likely to share the same cluster as the destination node, hence allowing a successful transmission with minimal utilization of resources or computational power. If such a node is not found in the neighbourhood of the transmitting node, it searches for a node that most closely resembles the desired properties of the next hop. The process shall continue until a node is found that shares the cluster with the destination node.

Chapter 6

EXPECTED OUTCOME OF THE RESEARCH

The proposed routing protocol is being implemented using the Opportunistic Network Environment abbreviated as ONE simulator. ONE is a java based platform used for generating node movements by using various mobility models. This allows us to visualise both the passing of messages in real time and visualise the data through its Graphical User Interface (GUI). In order to obtain the results of the protocol, compare with some already existing latest protocols. For the purpose of evaluation, I make use of the following performance metrics.

- Message Delivery Probability: These metric amounts to messages that successfully reached the delivery destination. A higher delivery probability is a positive indicator and signifies a higher delivery capability of the scheme. The metric ranges from 0 to 1.

- Average Hop Count: This is the average number of nodes in-between travelled by a message to arrive to its destination. A hop count lower in magnitude is an indicator of a better routing scheme in OppIoT scenario.

- Network Overhead Ratio [NOR]: This metric is essentially delta between the total number of transmitted messages and delivered messages. A lower value of Overhead Ratio indicates lesser processing time hence the objective of the routing proposed protocol is to minimise this quantity for more optimised performance.

- Time to live [TTL]: This metric indicate how much time a message lives in a network and deliver messages before they get decays or dies.

Chapter 7

REFERENCES

[1] L. Lilien, A. Gupta, Z. Yang. "Opportunistic networks for emergency applications and their standard implementation framework", *IEEE Intl. Performance, Computing, and Communications Conference (IPCCC 2007)*, vol. 1, 2007.

[2] K. Fall. A Delay-Tolerant Network Architecture for Challenged Internets. *In ACM SIGCOMM*, Aug., 2003.

[3] L-J. Chen, C. Hung Yu, C. Tseng, H. Chu, C. Chou. "A Content-Centric Framework for effective Data Dissemination in Opportunistic networks*". IEEE Journal on selected Areas in Communications*, vol. 26, No. 5, June 2008.

[4] Bluetooth, The Bluetooth Specification, v.1.0B [referred 2000/03/15] *http://www.bluetooth.com/ developer/specification/specification.asp*.

[5] WiFi, *http://www.wifinotes.com*

[6] Cellular networks, http://www.cellular.co.za/cellular networksoverview.htm

[7] R. Scopigno, M. Spirito (ISMB); I. Korpeoglu, A. R. Ulucinar (Bilkent/KHAS); A. L. Moustakas (NKUA/IASA); L. Galluccio, A. Leonardi (CNIT-CT); F. Fabbri, R. Verdone (CNIT-BO); C.F. Chiasserini (CNIT-TO); A. Zanella, F. Zorzi (CNIT-PD); R. Ferrus, F. Novillo (UPC); M. Boc, M. Dias de Amorim (CNRS/LIP6); J. Riihijarvi (RWTH); A. Brunstrom, M. Cavalcanti de Castro "State of the art of research on opportunistic networks, and definition of a common framework for reference models and performance metrics" *NEWCOM++ 216715, DR.11.1*. 54 pages.

[8] L. Pelusi, A. Passarella, M. Conti. "Opportunistic networking: Data forwarding in disconnected mobile ad hoc networks". *IEEE Communications Magazine*, vol. 44, pp. 134–141, Nov 2006.

[9] C.-M. Huang, K.-C. Lan, C.-Z. Tsai. "A survey of opportunistic networks". *Proc. of the 22nd Intl. Conference on Advanced Information Networking and Applications (WAINA)*, Biopolis, Mar. 25-28, Okinawa, Japan, 2008.

[10] S. Jain, K. Fall, R. Patra. **"**Routing in a Delay Tolerant Network". *Proc. of ACM SIGCOMM*, pp. 145–158, 2004.

[11] T. Spyropoulos, K. Psounis, C. S. Raghavendra. “Single-copy routing in intermittently connected mobile Networks”. *Proc. of Sensor and Ad Hoc Communications and Networks (SECON)*, pp. 235-244, Oct. 2004.

[12] A. Vahdat, D. Becker. **“**Epidemic routing for partially connected ad hoc networks”. *Technical Report CS-2000-06, Dept. of Computer Science, Duke University*, Durham, NC, 2000.

[13] T. Spyropoulos, K. Psounis, C. S. Raghavendra. “Spray and wait: An efficient routing scheme for intermittently connected mobile networks”. *Proc. of ACM SIGCOMM Workshop on Delay-Tolerant Networking (WDTN ’05),* pp. 252–259, 2005.

[14] A. Lindgren, A. Doria, and O. Schelen.“Probabilistic routing in intermittently connected networks”. *ACM SIGMOBILE, Mobile Computing and Communications Review*, vol. 7, no. 3, pp. 19–20, 2003.

[15] J. Burgess, B. Gallagher, D. Jensen, and B. N. Levine. “Maxprop: Routing for vehicle-based disruption-tolerant networks”. *Proc. of IEEE INFOCOM 2006*, pp. 1–11, 2006.

[16] M. Musolesi, S. Hailes, and C. Mascolo, “Adaptive Routing for Intermittently Connected Mobile Ad Hoc Networks,” *Proc. 6th IEEE Int’l. Symp. World of Wireless, Mobile and Multimedia Networks (WoWMoM 2005)*, Taormina-Giardini Naxos, Italy, June 13–16, 2005.

[17] A. Keranen. “Opportunistic Network Environment Simulator”. *Special Assignment Report, Helsinki University of Technology, Dept. of Communications and Networking*, May 2008.

[18] Libo Song and David F. Kotz. Evaluating opportunistic routing protocols with large realistic contact traces. In *CHANTS ’07: Proceedings of the second ACM workshop on Challenged networks*, pages 35–42, New York, NY, USA, 2007. ACM.

[19] A. Nordrum, "Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated", *IEEE Spectrum: Technology, Engineering, and Science News*, 2016.

[20] A. Jain, R. Crespo and M. Khari, “Smart innovation of web of things”, *1st ed. Boca Raton: CRC Press*, 2020, pp. 21-51.

[21] B. Dorsemaine, J. Gaulier, J. Wary, N. Kheir and P. Urien, "Internet of Things: A Definition & Taxonomy", *9th International Conference on Next Generation Mobile Applications, Services and Technologies*, 2015.

[22] D. Sharma, Aayush, A. Sharma and J. Kumar, "KNNR:K-nearest neighbour classification based routing protocol for opportunistic networks", *Tenth International Conference on Contemporary Computing (IC3)*, 2017.

[23] D. Sharma, S. Dhurandher, I. Woungang, R. Srivastava, A. Mohananey and J. Rodrigues, "A Machine Learning-Based Protocol for Efficient Routing in Opportunistic Networks", *IEEE Systems Journal*, vol. 12, no. 3, pp. 2207-2213, 2018.

[24] D. K. Sharma, S. K. Dhurandher, D. Agarwal, K. Arora, "krop: k-means clustering based routing protocol for opportunistic networks", *Journal of Ambient Intelligence and Humanized Computing* (2018) 1–18.

[25] E. Golden Julie and S. Tamilselvi, "CDS-Fuzzy Opportunistic Routing Protocol for Wireless Sensor Networks", *Wireless Personal Communications*, vol. 90, no. 2, pp. 903-922, 2016.

[26] K. Ahmad, M. Fathima, V. Jain and A. Fathima, "FUZZY-PRoPHET: a novel routing protocol for opportunistic network", *International Journal of Information Technology*, vol. 9, no. 2, pp. 121-127, 2017.

[27] K. Bhardwaj, S. Banyal and D. Sharma, "Artificial Intelligence Based Diagnostics, Therapeutics and Applications in Biomedical Engineering and Bioinformatics", *Internet of Things in Biomedical Engineering*, pp. 161-187, 2019.

[28] K. Liu, Z. Chen, J. Wu and L. Wang, "FCNS: A Fuzzy Routing-Forwarding Algorithm Exploiting Comprehensive Node Similarity in Opportunistic Social Networks", *Symmetry*, vol. 10, no. 8, p. 338, 2018.

[29] M. Anisi, A. Abdullah, Y. Coulibaly and S. Razak, "EDR: efficient data routing in wireless sensor networks", *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 12, no. 1, p. 46, 2013. Available: 10.1504/ijahuc.2013.051390.

[30] M. Gupta, S. Dhurandher and P. Nicopolitidis, "A Novel and Efficient Geocasting in OppNets", *International Conference on Computer, Information and Telecommunication Systems (CITS)*, 2018.

[31] N. Chakchouk, "A Survey on Opportunistic Routing in Wireless Communication Networks", *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2214-2241, 2015.

[32] P. Sok, S. Tan and K. Kim, "PRoPHET Routing Protocol Based on Neighbor Node Distance Using a Community Mobility Model in Delay Tolerant Networks", *2013 IEEE 10th International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing*, 2013.

[33] S. Bagga, N. Chawla, D. K. Sharma and D. Kukreja, "Fuzzy Logic based Clustering Algorithm to Improve DEEC Protocol in Wireless Sensor Networks," *2019 International Conference on Computing, Power and Communication Technologies (GUCON)*, NCR New Delhi, India, 2019, pp. 212-216.

[34] S. Banyal, K. Bhardwaj, and D. Sharma, "Probabilistic routing protocol with firefly particle swarm optimisation for delay tolerant networks enhanced with chaos theory", *Int. J. Innovative Computing and Applications*, Vol. 12, No. 2, pp.25-37.

[35] S. Pal, V. García Díaz and D. Le, IoT, 1st ed. Boca Raton: CRC Press, 2020, pp. 134-157.

[36] V. Vashishth, A. Chhabra and D. Sharma, "A Machine Learning Approach Using Classifier Cascades for Optimal Routing in Opportunistic Internet of Things Networks," *16th Annual IEEE International Conference on Sensing, Communication, and Networking (SECON)*, Boston, MA, USA, 2019, pp. 1-9, 2019.

[37] V. Vashishth, A. Chhabra and D. Sharma, "GMMR: A Gaussian mixture model based unsupervised machine learning approach for optimal routing in opportunistic IoT networks", *Computer Communications*, vol. 134, pp. 138-148, 20

[38] D. Sharma, J. Rodrigues, V. Vashishth, A. Khanna and A. Chhabra, "RLProph: A dynamic programming based reinforcement learning approach for optimal routing in opportunistic IoT networks", *Wireless Networks*, vol. 26, no. 6, pp. 4319-4338, 2020.

MANAV RACHNA
Vidyaparikshat

Swami Vivekananda Library and Resource Centre
Manav Rachna University

SIMILARITY VERIFICATION CERTIFICATE

Title: Design and analysis of Coherent Routing protocols for message forwarding in opportunistic IOT Networks.

Researcher: S.P. Ajith kumar Registration Number: 2K19-PFE-005

Supervisor: Dr. Hardeo kumar Thakur Department: C.S.T.

This is to certify that the above mentioned Short Synopsis/~~Thesis~~ was scanned for similarity index through Turnitin Software on 26/10/2020 with submission ID 1426773280 and the similarity index was found to be 6 %. The complete report running into 26 Pages, 6684 Word count with File Size 3755 KB is being forwarded to the Research Supervisor/DRC/DRB for review.

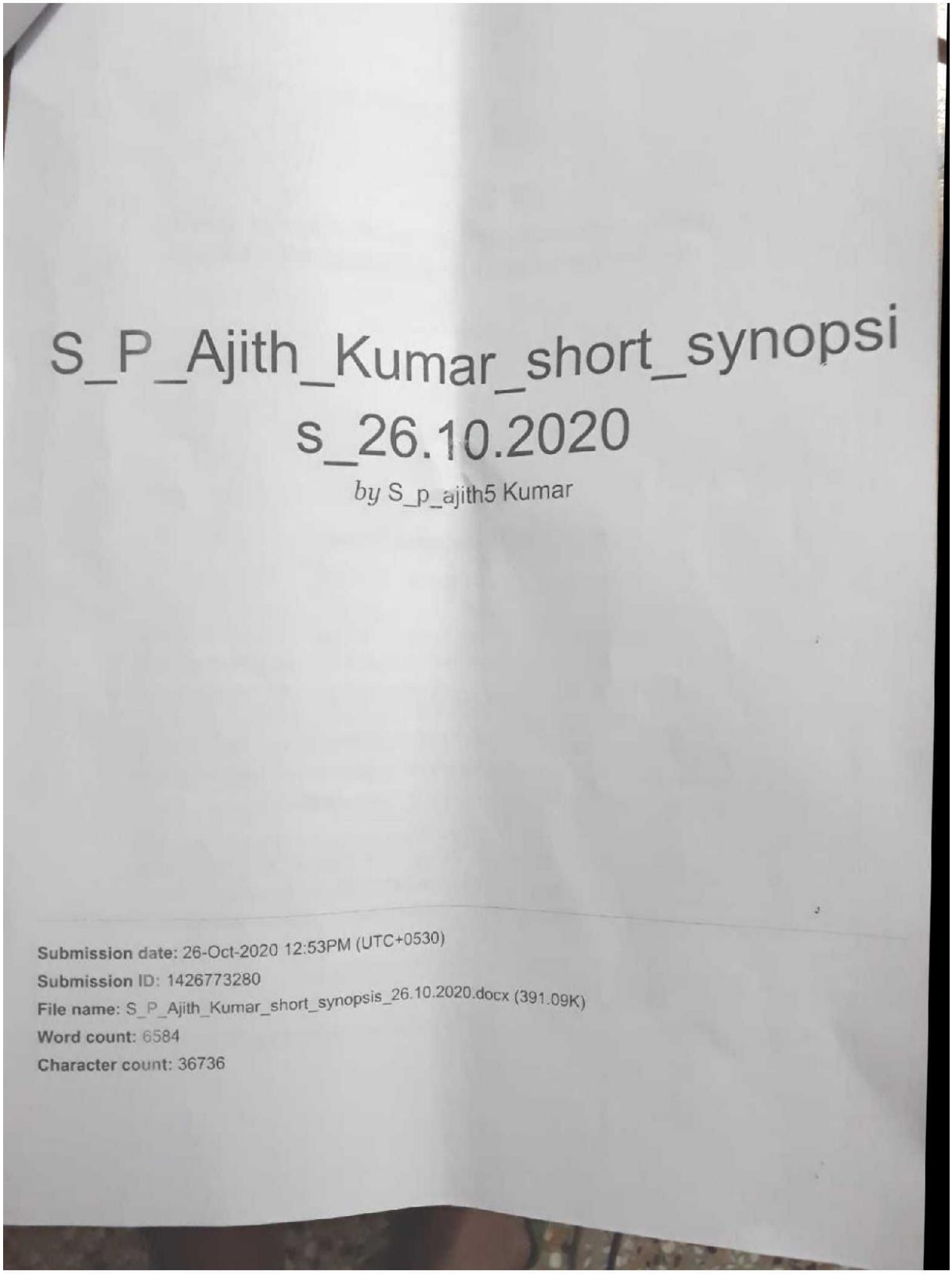
Date: 29/10/2020

Swami Vivekananda Library and Resource Centre, Faridabad * Manav Rachna University *
29/10/2020

The complete report of the above Short Synopsis/~~Thesis~~ has been reviewed and the similarity index is below the accepted norms as per the University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018. The Short Synopsis/~~Thesis~~ may be considered for further processing

Research Scholar

Hardeo
Research Supervisor
29/10/2020



S_P_Ajith_Kumar_short_synopsis_26.10.2020

by S_p_ajith5 Kumar

Submission date: 26-Oct-2020 12:53PM (UTC+0530)
Submission ID: 1426773280
File name: S_P_Ajith_Kumar_short_synopsis_26.10.2020.docx (391.09K)
Word count: 6584
Character count: 36736

MANAV RACHNA
MANAV RACHNA UNIVERSITY
NAAC ACCREDITED 'A' GRADE INSTITUTION

Design and analysis of Coherent Routing Protocols for message forwarding in Opportunistic IoT Networks

SHORT SYNOPSIS

by

S P Ajith Kumar
2K19-PFE-005

Under the supervision of

Dr. Hardeo Kumar Thakur

ABSTRACT

Opportunistic Internet of Things [OpploT] networks are one of the effective evolutions of Delay Tolerant Networks (DTNs). OpploTs are different from Internet of Things network as end-to-end routing paths may not be available from the source to destination. It operates in an intermittent, mobile communication topology, employing peer-to-peer transmission, hops on a store-carry-forward basis. In this network routes are building dynamically, whenever messages are routed from the source to destination(s), any potential node will act as the next hop, bringing the message nearer to the destination.

This is necessary to develop routing protocols which are able to increase the message delivery possibility and decrease the delivery failure possibility. Many protocols like Epidemic, PROPHET, Spray and Wait, MLPROPH, KNNR, GMMR etc... used in Opportunistic IoT networks. Most of these protocols suffer from overheads like higher power

S_P_Ajith_Kumar_short_synopsis_26.10.2020

6% SIMILARITY INDEX | 3% INTERNET SOURCES | 6% PUBLICATIONS | 0% STUDENT PAPERS

Excluding matches less than 14 words

Sathyabama Institute of Science and Technology Library and Resource Centre

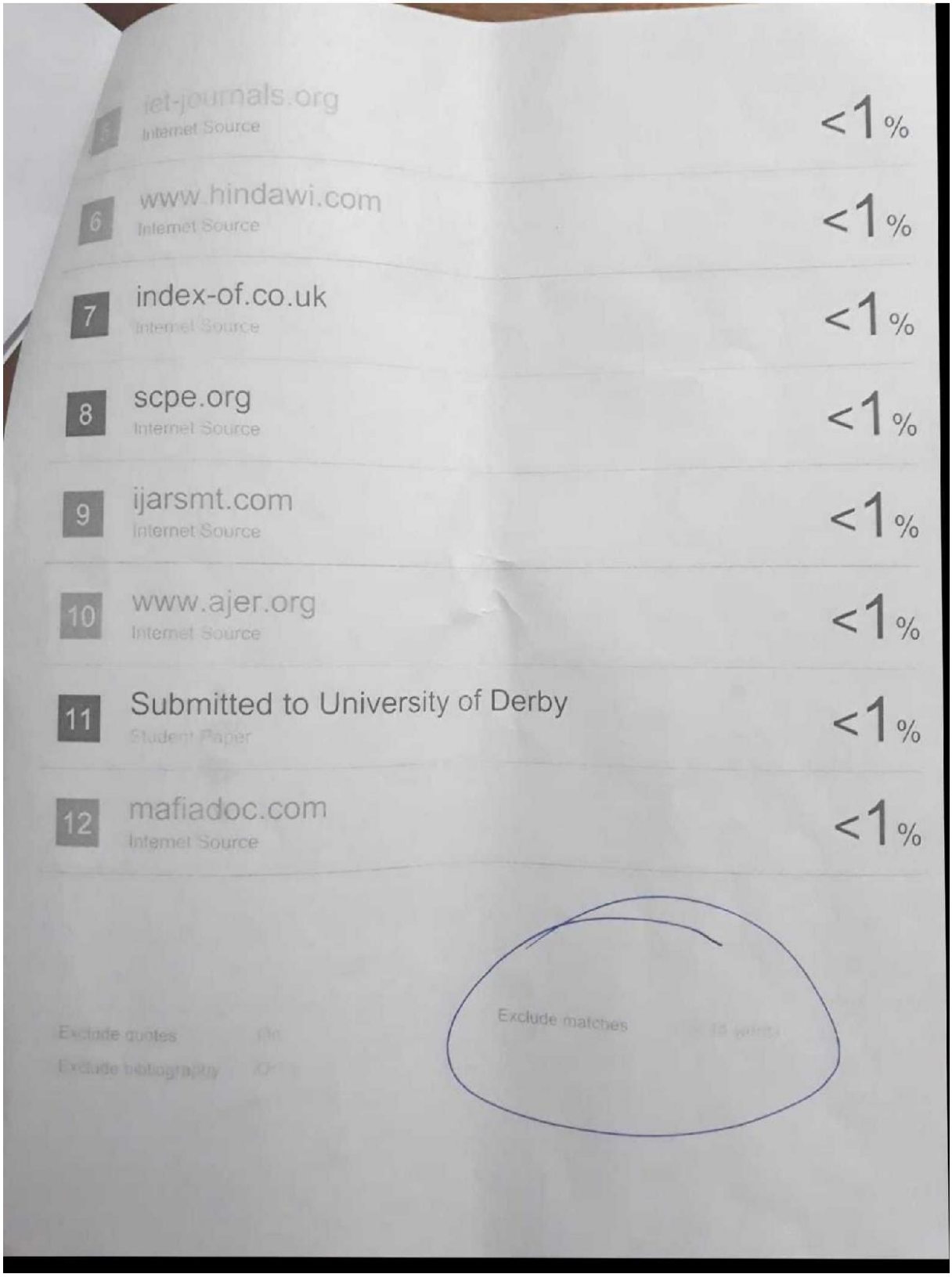
Seal Vinayagananda Library and Resource Centre Sathyabama Institute of Science & Technology Deemed to be University Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119

24/10/2020

Itsmeo

21/10/2020

1	Vidushi Vashishth, Anshuman Chhabra, Deepak Kumar Sharma. "GMMR: A Gaussian mixture model based unsupervised machine learning approach for optimal routing in opportunistic IoT networks", Computer Communications, 2018 Publication	1%
2	Sanjay K. Dhurandher. "Performance evaluation of various routing protocols in Opportunistic Networks", 2011 IEEE GLOBECOM Workshops (GC Wkshps), 12/2011 Publication	1%
3	Deepak Kumar Sharma, Joel J. P. C. Rodrigues, Vidushi Vashishth, Anirudh Khanna, Anshuman Chhabra. "RLProph: a dynamic programming based reinforcement learning approach for optimal routing in opportunistic IoT networks", Wireless Networks, 2020 Publication	1%
4	Routing in Opportunistic Networks, 2013 Publication	<1%


iet-journals.org
Internet Source
<1%
6
www.hindawi.com
Internet Source
<1%
7
index-of.co.uk
Internet Source
<1%
8
scpe.org
Internet Source
<1%
9
ijarsmt.com
Internet Source
<1%
10
www.ajer.org
Internet Source
<1%
11
Submitted to University of Derby
Student Paper
<1%
12
mafiadoc.com
Internet Source
<1%
Exclude matches